Appl. No. 10/090,761
Amendment dated June 24, 2004
Reply to Office Action of March 24, 2004

IN THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Claim 1 (Currently Amended):   A plasma-based method of etching a film of hardly-etched material formed on a substrate using said film and a mask formed on said hardly-etched film, said method comprising the step of:

etching said film of hardly-etched material using said mask having a side wall angled at 90 degrees or less which surface forms an angle of substantially θ with respect to [[the]]a surface of said substrate, said θ being given by tan Φ = (re-rd) / ((rd-re x cosθ) x sinθ) supporting that said Φ is a target tapered angle of said film of hardly-etched material after being etched, wherein re is an etching rate of said film of hardly-etched material and rd is a deposition rate of reaction product to said side wall.

Claim 2 (Currently Amended):   An etching method according to claim 1, wherein:

said film is one selected from [[a]]the group of materials consisting of Fe, Co, Mn, Ni, Pt, Ru, RuO2, Ta, Ir, IrO2, Os, Pd, Au, Ta2O5, PZT, BST, SBT, Al2O3, HfO2, ZrO2, GaAs and ITO.

Claim 3 (Currently Amended):   A plasma-based method of etching a film of hardly-etched material formed on a substrate using said film and a mask formed on said hardly-etched film, said method comprising the step of:

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etching said film of hardly-etched material using said mask having a side wall formed with a taper angle of ~~less than 90 degrees~~substantially θ with respect to ~~the~~a surface of said substrate, to form ~~said~~an etched film with a taper angle with respect to the surface of said substrate equal to or larger than the taper angle of said mask, said θ being given by tan Φ = (re-rd) / ((rd-re x cosθ) x sinθ), wherein said Φ is a target tapered angle of said film of hardly-etched material after being etched, re is an etching rate of said film of hardly-etched material and rd is a deposition rate of reaction product to said side wall.

Claim 4 (Currently Amended):   A plasma-based method of etching a film of hardly-etched material formed on a substrate using said film and a mask formed on said hardly-etched film, said method comprising the steps of:

forming said mask such that a side wall of [[sad]]said mask has a taper angle of substantially θ with respect to the surface of said substrate, ~~less than 90 degrees~~said θ being given by tan Φ = (re-rd) / ((rd-re x cosθ) x sinθ); and

etching said film of hardly-etched material using said mask, wherein said Φ is a target tapered angle of said film of hardly-etched material after being etched, re is an etching rate of said film of hardly-etched material and rd is a deposition rate of reaction product to said side wall.

Claim 5 (Original):   A method of etching a film of hardly-etched material according to claim 4, wherein:

said step of forming said mask includes the step of etching said mask.

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Claim 6 (Original):   A method of etching a film of hardly-etched

material according to claim 5, wherein:

said step of etching said mask includes the step of adjusting an etching

condition for said mask to adjust the taper angle of said mask.

Claim 7 (Original):   A method of etching a film of hardly-etched

material according to claim 6, wherein:

said etching condition is at least one of a composition of a gas introduced into

an etching chamber and an etching pressure.

Claim 8 (Original):   A method of etching a film of hardly-etched

material according to claim 5, wherein:

said step of etching said mask includes the step of adjusting at least one of a

thickness of said film and an etching time for said mask to adjust the taper angle of

said mask.

Claim 9 (Original):   A method of etching a film of hardly-etched

material according to claim 5, wherein:

said step of etching said mask includes the step of adjusting at least one of

the size of a photoresist mask formed on said mask, and an etching time for said

mask to adjust the taper angle of said mask.

Claim 10 (Currently Amended):   A method of etching a film of hardly-

etched material according to claim 5, wherein:

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said step of etching said mask includes the steps of washing said mask in the middle of etching said mask by dry etching, and subsequently etching again said mask by wet etching.

Claim 11 (Original):   A method of etching a film of hardly-etched material according to claim 10, wherein:

said step of etching said mask includes the step of adjusting at least one of the size of a photoresist mask formed on said mask, and an etching time for said mask before said step of washing to adjust the taper angle of said mask.

Claim 12 (Currently Amended):   A method of etching a film of hardly-etched material according to claim 4, wherein:

said film is one selected from [[a]]the group of materials consisting of:

Fe, Co, Mn, Ni,

Pt, Ru, RuO2, Ta, Ir, IrO2, Os, Pd, Au, Ti, TiOx, SrRuO3, (La, Sr)CoO3,

Cu(Ba, Sr)TiO3, SRO: SrTiO3, BTO: BaTiO3, SrTa2O6, Sr2Ta2O7, ZnO, Al2O3,

ZrO2, HfO2, Ta2O5, Pb(Zr, Ti)O3, Pb(Zr, Ti)Nb2O8, (Pb, La)(Zr, Ti)O3, PbTiNbOx,

SrBi2Ta2O9, SrBi2(Ta, Nb)2O9, Bi4Ti3O12, BiSiOx, Bi4-xLaxTi3O12, and InTiO.

Claim 13 (Currently Amended):   A method of fabricating a semiconductor device using at least one layer of hardly-etched material formed on a substrate, and a mask formed on said hardly-etched film, said method comprising the steps of:

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performing a first etching of said layer of hardly-etched material by a predetermined amount using said mask, during which a first part of said layer exposed for the first time by said first etching is formed with a first taper angle θ with respect to a surface of said substrate;

washing out an etching product in the middle of the etching; and

~~again~~ performing a second etching of said layer of hardly-etched material by a remaining amount using said mask, during which a second part of said layer exposed for the first time by said second etching is formed with a second taper angle of substantially Φ with respect to the surface of said substrate given by $\tan \Phi = (re\text{-}rd) / ((rd\text{-}re \times \cos\theta) \times \sin\theta)$, wherein the second taper angle is larger than the first taper angle, and wherein re is an etching rate of said film of hardly-etched material and rd is a deposition rate of reaction product to said side wall.

Claim 14 (Currently Amended): A semiconductor device fabricated by the method of manufacturing a semiconductor device according to claim 13, comprising:

a substrate; and

at least one layer of hardly-etched material formed on said substrate, said layer of hardly-etched material having a side wall, the taper ~~angel~~ angle of which changes in the middle of said side wall.

Claim 15 (Original): A semiconductor device fabricated by the method of manufacturing a semiconductor device according to claim 13, comprising:

a substrate; and

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at least two layers of hardly-etched material formed on said substrate,

wherein one of said at least two layers of hardly-etched material is formed with a

side wall having a taper angle different from a taper angle of a side wall of the other

layer of hardly-etched material.

Claim 16 (Currently Amended):   An etching method for attaching a

reaction product on [[a]]an inner wall of a vacuum chamber of an etching apparatus

which is arranged in a manner that a high frequency current is supplied to a coil

provided on an outer peripheral portion of said vacuum chamber to generate plasma

within said vacuum chamber, etching gas is introduced into said vacuum chamber

through a gas introducing port and exhausted from an exhauster, and an

electrostatically coupled antenna grounded through a load is provided on the outer

peripheral portion of said vacuum chamber, comprising the step of:

continuously attaching said reaction product to the inner wall of said etching

apparatusvacuum chamber until at least one wafer has been processed in a state

that an impedance of said load is reduced to make an amount of current flowing into

said electrostatically coupled antenna small, such that an etched material formed on

a substrate within said vacuum chamber has a side wall angled substantially at 90

degrees with respect to the surface of said substrate.

Claim 17 (Original):   An etching method according to claim 16,

further comprising the step of:

periodically removing said reaction product attached on the wall of said

etching apparatus.

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Claim 18 (Original):   An etching method according to claim 16, further comprising the step of:

etching the etched material using a mask having a side wall angled at less than 90 degrees with respect to the surface of said substrate.

Claim 19 (Currently Amended):   A method of etching a material under processing using a semiconductor device fabricating apparatus comprising a wafer carrier, a plurality of processing chambers and a plurality of post-processing chambers connected to said wafer carrier, a plurality of lock chambers, and an atmosphere carrier located adjacent to said lock chambers, wherein said atmosphere carrier can be connected to said plurality of lock chambers, and a wafer cassette adjacent to said atmosphere carrier, said method comprising the steps of:

etching the material under processing in one of said plurality of processing chambers;

post-processing the material under processing in one of said plurality of post-processing chambers thereby to remove deposition material from a side wall of the material under processing;

etching the material in one of said plurality of processing chambers; and

post-processing the material under processing in one of said plurality of post-processing chambers.

Claim 20 (Currently Amended):   A method of etching a material under processing using a semiconductor device fabricating apparatus comprising a wafer

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carrier, a plurality of processing chambers connected to said wafer carrier, a plurality

of lock chambers, and an atmosphere carrier located adjacent to said lock

chambers, wherein said atmosphere carrier can be connected to said plurality of lock

chambers, a post-processing chamber adjacent to said atmosphere carrier, and a

wafer cassette adjacent to said atmosphere carrier, said method comprising the

steps of:

etching the material under processing in one of said plurality of processing

chambers;

post-processing the material under processing in said post-processing

chamber thereby to remove deposition material from a side wall of the material under

processing;

etching the material in one of said plurality of processing chambers; and

post-processing the material under processing in said post-processing

chamber.

Claim 21 (Cancelled):

Claim 22 (New):   A plasma-based method of etching a film of hardly-

etched material formed on a substrate using said film and a mask formed on said

hardly-etched film, said method comprising the step of:

etching said film of hardly-etched material using said mask having a side wall

which surface forms an angle of substantially θ with respect to a surface of said

substrate, said θ being a root given by tan Φ = (re-rd) / ((rd-re x cosθ) x sinθ)

supposing that said Φ is a maximum value of a target tapered angle of said film of

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hardly-etched material after being etched, wherein re is an etching rate of said film of

hardly-etched material and rd is a deposition rate of reaction product to said side

wall.

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